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GEOCHEMISTRY.—*The various forms of silica and their mutual relations.* CLARENCE N. FENNER, Geophysical Laboratory.
Communicated by Arthur L. Day.

Character of the investigation

Problems presented by the various forms of silica occurring in nature, in the relations which they bear to each other, have been the subject of investigation by a number of experimenters. The results obtained have not been altogether concordant and the present investigation was undertaken in order to reconcile or explain these discrepancies if possible and to obtain such additional information as would definitely establish the equilibrium relations of the various forms. The investigation is not yet concluded, but the general relations have been established and can be stated with confidence. Later, the whole will be presented at length and with full details of apparatus and methods of work.

The first subject of investigation was the determination of the exact relations between quartz, tridymite, and cristobalite. Two principal difficulties were encountered. First, the velocity of transformation of one form into another is extremely small at most temperatures; and second, it was found that silica possesses pre-eminently the property which Ostwald has expressed in his principle of successive reactions, namely, that a given form when subjected to conditions under which it is unstable,

frequently does not pass directly into the form which is most stable under those conditions, but first into some less unstable condition, and only after a lapse of time into the stable form.

Because of the sluggishness of transformation the writer has not found it possible, without employing a catalytic agent, to convert quartz into tridymite at any temperature, but at temperatures in the neighborhood of 1400°C. quartz gradually changes into cristobalite. 1400° is still well below the temperature at which cristobalite is stable, but in the passage from quartz to tridymite cristobalite is reached and there the process halts. It is only by the addition of a small quantity of some catalytic agent, such as tungstate of soda, that the reaction proceeds to completion. A parallel case is afforded in the transformation of silica glass into quartz at a temperature of 850°. In the course of a few hours it becomes converted into tridymite, but this is only an intermediate stage, for after a much longer time at the same temperature crystals of quartz make their appearance, and this is in reality the stable form at that temperature. It was only after much experimenting that such facts were fully brought out and their significance appreciated.

Inversion of quartz to tridymite

When finely ground quartz is heated with tungstate of soda it remains unchanged until a temperature of about 870° is reached. At temperatures above 870° it is gradually converted into tridymite. Near the inversion temperature the reaction proceeds very sluggishly so that it is only after the lapse of several days that identifiable tridymite appears.

At higher temperatures the change proceeds more rapidly. In several experiments conducted at about 1300° for 24 hours the surface of the cake in the crucible showed comparatively large crystals, easily visible to the naked eye.

As tridymite, in passing from the temperature of formation to ordinary temperatures, goes through a second inversion point the crystals lose hexagonal symmetry as regards optical properties but retain the outward form. The hexagonal plates therefore are not isotropic but are divided into faintly birefringent fields.

These show a biaxial, positive figure, with the acute bisectrix normal to the plate. Three determinations of the value of the optic axial angle gave for 2V an average of 35½°. The index of refraction, as determined by the immersion method, is 1.475.

When tridymite, prepared at a high temperature as described, is in turn heated with a little tungstate of soda at temperatures below 870°, the transformation is reversed and quartz is formed. The relation of the two is therefore enantiotropic.

Inversion of tridymite to cristobalite

Tridymite is stable at all temperatures from 870° ± 10° up to 1470° ± 10°, where the inversion to cristobalite takes place. Like the inversion of quartz into tridymite that of tridymite into cristobalite, even in the presence of tungstate of soda, is very slow near the inversion point, but proceeds more rapidly at higher temperatures. At 1570° the reaction is complete in a few hours. At temperatures below 1470° cristobalite is reconverted into tridymite. The relations between tridymite and cristobalite are therefore analogous to those between quartz and tridymite.

As cristobalite also passes thru a low-temperature inversion-point in cooling to room temperatures the grains are not isotropic, but posses a faint birefringence.

The grains have been too small to determine the optical character with certainty, but some of maximum birefringence were found to give a fairly satisfactory interference figure, apparently perpendicular to the optic normal. The acute bisectrix was then found to be α and the mineral may provisionally be considered negative. The index of refraction as determined by the immersion method is close to 1.485.

From 1470° no further change was found to take place up to the melting point. The latter was considered by Day and Shepherd to be about 1600°.[1] No further information has been obtained with regard to this.

Silica glass, when devitrified without a flux, passes into cristo-

[1]The Lime-Silica Series of Minerals, Am. Jour. Sci., 4th ser., **22**: 265–302. October, 1906.

balite, even at temperatures below 1470°. From this intermediate stage the transformation to tridymite can be completed only with the assistance of a flux. Below 870°, even with tungstate of soda present, the glass is transformed first to tridymite and only very slowly to quartz. Precipitated silica behaves in the same manner as silica glass and is probably to be considered as strictly amorphous and analogous to the fused material.

The mutual relations of the three crystalline minerals and the amorphous forms have been repeatedly confirmed. Quartz has been converted into tridymite and into cristobalite; tridymite into quartz and into cristobalite; and cristobalite into quartz and into tridymite. Moreover in numerous cases where, in conformity with Ostwald's principle, intermediate stages have been reached, it has been found without exception that by longer heating or by the use of a catalytic agent the appropriate stable form can be attained.

Preparation of quartz in aqueous solutions

Quartz may be prepared with facility by heating either silica glass or amorphous, precipitated silica in a steel bomb with water and sodic carbonate at 400° to 500° for two or three days.

In a slightly varying form of experiment artificial tridymite was employed and quartz crystals were obtained as usual. Artificial cristobalite likewise recrystallized as quartz. In no case has the presence of tridymite or cristobalite in preparations made in aqueous solution been detected, but, on the contrary, when the higher forms of silica have been used they have recrystallized as quartz.

Other inversions

The inversions of silica thus far described are characterized by a complete change in the outer form of the mineral, and can only be produced slowly and with difficulty. There is, however, a second class of inversions which take place almost instantaneously. The outer form of the mineral is retained, but the internal structure must necessarily be modified. These are the transformations of α- into β-quartz, of α- into β-tridymite, and of

α- into β-cristobalite. The method chiefly employed in investigation was that of heating-curves.

Inversion of α-quartz into β-quartz. By optical methods this inversion had previously been placed at 575°. The writer confirmed this, finding a well-defined break in the heating-curve at 576°. The change has been regarded as one from tetartohedral to hemihedral symmetry of the crystals.

Inversion of α-tridymite into β-tridymite. The hexagonal plates of tridymite are birefringent at ordinary temperatures, even on basal sections, but when heated they suddenly become isotropic. The inversion point has been placed by F. E. Wright at about 120°.

By the use of heating-curves the writer has found what appear to be two inversions, one at 117° and another, less pronounced but quite sharp, at 162°. The significance of this is not readily apparent and more investigation is required.

Inversion of α-cristobalite into β-cristobalite. The temperature at which the birefringent, low-temperature form changes to the isotropic state appropriate to the external symmetry of the crystals was placed by Mallard at 180°. F. E. Wright, working on spherulites formed by the devitrification of silica glass, found that Mallard's point was too low and determined it as approximately 225°. The writer, making use of cristobalite formed in various ways, and employing both optical methods and heating-curves, obtained rather remarkable results. On different preparations the point at which the break occurs on the heating curve has been found as high as 274°.0 and as low as 240°.1. On the cooling curve the break occurs as high as 236°.6 and as low as 209°.3. The first results obtained were much higher than the figures of Mallard and of Wright, and the explanation which suggested itself was that the abnormally high temperatures were due to hysteresis or to the presence of impurities in solid solution, but these possibilities were eliminated. It was found, however, that the temperature to which the silica was heated in con-

verting it into cristobalite, was certainly a factor affecting the inversion point of the resultant product, but it could not be considered that the whole effect was due to this cause. Such wide variations in the inversion point of a mineral appear very remarkable. A certain analogy is suggested to the behavior of antimony upon freezing.[2]

Relation of chalcedony to other forms of silica

The relation of chalcedony to quartz has been the subject of considerable discussion. As optical methods appear to have been pursued as far as possible without obtaining conclusive evidence, the writer has endeavored to attain a solution by working along other lines, and certain results of significance have been obtained. As quartz shows a sharp break at 575°, chalcedony should, if it is identical with quartz, show the same break. The region on both sides of 575° has been carefully explored by means of heating-curves, but so far chalcedony has failed to give any trace of a break.

A second class of experiments has had for their object the determination of the form into which chalcedony would invert when heated with sodic tungstate to temperatures near to but lower than 870°. A number of experiments have resulted in the formation of tridymite and of new quartz crystals.

On the supposition that chalcedony is the same mineralogically as quartz it is difficult to interpret these results, but on the supposition that it represents a different phase the results are perfectly consistent. The evidence therefore points to the existence of still another form of silica in chalcedony.

Recapitulation of inversions

The various inversions of silica may be briefly recapitulated.

At some unknown, but probably rather low temperature chalcedony passes into α-quartz (tetartohedral hexagonal), (the relation between the two may be monotropic),

575° α-quartz $\rightleftarrows$ β-quartz (hemihedral hexagonal),

[2] A. L. Day and R. B. Sosman, Am. Jour. Sci., 4th ser., **29**: 126. February, 1910.

870° ± 10° β-quartz $\rightleftarrows$ β-tridymite (holohedral hexagonal),

1470° ± 10° β-tridymite $\rightleftarrows$ β-cristobalite (isometric).

The above are all stable forms, each with a certain range of temperature, but on cooling β-tridymite or β-cristobalite, metastable forms result, as follows:

115°–120° β-tridymite $\rightleftarrows$ α-tridymite (biaxial, perhaps orthorhombic)

180°–270° (inversion point easily displaced and not definitely determinable) β-cristobalite $\rightleftarrows$ α-cristobalite (crystal character unknown, mineral may belong to any system but isometric).

There are thus apparently at least seven separate and distinct crystalline forms of silica.

It may be pointed out as a curious fact, whose significance is not known, that with rising temperature each form passes successively into one possessing a higher grade of crystallographic symmetry. Chalcedony, about which our knowledge is deficient, must, of course, be excluded from this general statement.

Geological Application

A brief examination may be made into the geological significance of the results which have been attained. Since the existence of tridymite and cristobalite became known the problem of the conditions under which they have been formed has been rather a baffling one. It is believed that from the results of this investigation answers may be given to some of the questions involved.

Ordinarily cristobalite forms crystalline deposits in small cavities in igneous rocks. These rocks bear evidence of having been subjected to corrosive agencies. The process of deposition may have involved a reaction between some volatile compound of silicon, such as the chloride or fluoride, with the vapor of water, or the decomposition of silicates or alumino-silicates by halogen acids, with the removal of the volatile halide and recrystallization of the silica. The difficulty which arises is to explain the deposition of cristobalite, whose field of stability lies above 1470°, in cavities in rocks which would certainly be in a

fluid condition at such a temperature, but in view of the repeated instances of the formation of cristobalite at temperatures well below the inversion point, which the writer has met in these investigations, the difficulty appears to vanish. It is quite probable that under such conditions as have been suggested cristobalite would be deposited at temperatures below 1470°.

With tridymite the case appears essentially the same. With either mineral it is only when in contact with a flux for a considerable length of time that the stable form is necessarily reached.

Effect of pressure upon the quartz-tridymite inversion point

All the inversion points which have been given have necessarily been determined under atmospheric pressure. It may be of interest to inquire into the effect which great pressure would have in increasing the range over which quartz is stable.

In the calculations which follow the numerical values which have been employed are only roughly approximate and at the best we can obtain merely the probable order of magnitude of pressure-effects.

For the purposes of the calculation we shall take the temperature of inversion under one atmosphere pressure as 870°, for the volume change a value derived from the differences in volume between quartz and tridymite at ordinary temperatures, or 0.057 cc. per gm., for the energy-change 15 calories, or approximately two-fifths of the energy involved in all the inversions from α-quartz to fused silica, according to the investigations of O. Mulert.[3] We may then employ the fundamental Clausius-Clapeyron formula, arranged as follows

$$\frac{dT}{dp} = \frac{T}{L}(v_2 - v_1)$$

in which $\frac{dT}{dp}$ is the increase in temperature for an increase of pressure of 1 gm. per cm^2.

[3] Zs. für Anor. Chem., Bd. 75, Heft 2, p. 206. May, 1912.

T = absolute temperature
L = latent heat, expressed in work units,
= $15 \times 4.1833 \times 1.02 \times 10^4$ gm. cm.*
= 15×42670 gm. cm.
$v_2 - v_1$ = increase in volume in cc. per gm.

By substitution

$$\frac{dT}{dp} = \frac{1143 \times 0.057}{15 \times 42670}$$

= 0.000102° for 1 gm. pressure per cm².
= 0.10537° per atmosphere.

Therefore 9.5 atmospheres will raise the inversion point 1°, and a column of rock 10,000 feet deep will raise the temperature 88°.

This is probably as close an approximation as we can attain with our present knowledge. In order to make a more precise calculation the specific volume of tridymite at high temperatures (up to and beyond 870°), and the energy-change involved in the transformation of quartz into tridymite must be determined. With this information available it should be possible to arrive at conclusions of great value regarding the conditions of temperature and pressure under which quartziferous rocks have crystallized.

Summary

The results of the investigation may be concisely stated as follows: Either tridymite or cristobalite may, under certain conditions, form at temperatures below their inversion-points. The favorable conditions, we believe, are those which induce rapid crystallization, such as the reactions of vapors or the sudden cooling of a melt. Either mineral, when formed under such circumstances, will probably persist to ordinary temperatures unchanged as regards the outer form. Quartz, on the other hand, will probably never be deposited at a temperature greater than 870° (i.e., neglecting the rather slight effect of pressure)

* 1 gm. cal. = 4.1833×10^7 ergs. (Landolt-Börnstein tables, p. 810.)
1 erg. = 1.02×10^{-3} kg. metres = 1.02×10^{-3} gm. centimetres.
∴ 1 gm. cal. = $4.1833 \times 1.02 \times 10^4$ gm. cm.

and if either tridymite or cristobalite, formed under any conditions, be kept in contact with a melt in which it is slightly soluble, for a comparatively short time at a temperature below 870°, it will pass over into quartz, and no record will be left of the previous existence of the higher form.

The α-β inversions of each of the three minerals are of a different class. They take place immediately when the appropriate temperature is passed in either direction, and the value of the α-β inversion-point of quartz at 575° as establishing a point on the geological thermometer, is left unchanged by the present investigation.

HELMINTHOLOGY.—*Further notes on Tricoma.* N. A. COBB. Communicated by F. V. Coville.

In the years 1888 and 1889, while carrying on some investigations at the zoological station at Naples, where thru the liberality of the British Association for the Advancement of Science, I had the use of one of its tables, I discovered a remarkable nematode—so remarkable indeed, that competent helmintholo-gists have repeatedly expressed doubt as to whether it is really a nematode.

Later a short note on this species was published in the *Proceedings of the Linnean Society*[1] (N. S. W.) under the title, *Tricoma* and other New Nematode Genera, concluding with the words "These few notes comprise all that is known concerning the structure of a worm, which, were it less remarkable, I should not notice at this writing."

The note in the *Proceedings* was accompanied by two carefully drawn figures, one of the head and the other of the tail. Unfortunately the only preserved specimen in existence at that time was lost immediately after the drawings were made, so that no further details were available. However, before the specimen was lost I had become thoroly satisfied that it was a nematode of typical internal organization, but with an unusual development of the cuticle. This development is so exceptional as

[1] Vol. viii (Series 2). October 25, 1893.

to obscure the natural relationships of the species. These first came to light thru a careful microscopic investigation of the internal anatomy.

Tho the published figures mentioned above are accurate so far as they go, they are unfortunately incomplete, and this incompleteness of observation led to the adoption of a generic name, *Tricoma*, which is misleading. Instead of three cephalic setae, there are four. Later researches have shown that the setae on these worms are very fragile, and even now, in spite of the examination of a larger number of specimens, a full knowledge of the setae has not been obtained. It is certain, however, that all the known species possess four cephalic setae.

During visits to the Island of Jamaica I have latterly come across a second species of *Tricoma*, inhabiting marine algae and adjacent sand. As very few specimens were found, the inference is that the individuals are not common. All those found came from near low tide mark on open, rocky sea-shores subject to the unosbstructed action of ocean waves. Soon after discovering the Jamaican species I received, thru the kindness of my friend, Mr. F. Muir of Honolulu, a collection of free-living nematodes from Larat, an island off the east end of New Guinea, and in this collection also there were a few specimens of *Tricoma*.

Prof. E. Bresslau, writing from Strassburg, informs me that he observed a specimen of *Tricoma cincta* on the coast of Heligoland in the North Sea.

It thus appears that *Tricoma* is a genus having a very wide distribution.

The accompanying figures are largely self explanatory. It is only necessary to add a few words concerning the missing features.

The single cephalic seta, *c*, was drawn from another specimen on which it grew. The setae, *bb*, drawn with dotted lines, are reconstructions on the basis of the seta, *c*. Here and there on the figures irregular scattered setae are shown. These are the ones that actually existed on the specimen drawn. The dots indicate the annules of the cuticle on which the stumps of broken off setae were observed. It will be seen, therefore, that

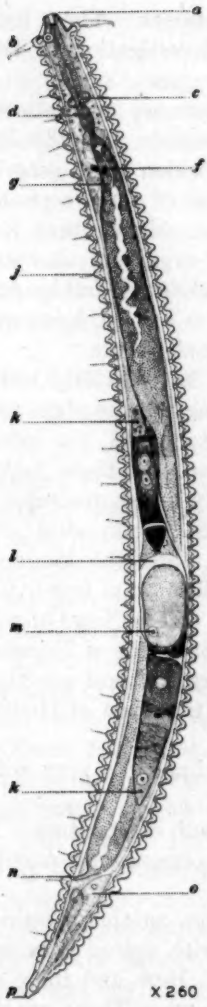

Fig. 1. Female of *Tricoma similis*, n. sp.

a, mouth opening and pharynx;
b, reconstructed cephalic seta;
c, nerve ring;
d, esophagus;
f, eye-spot;
g, intestine;
j, annule of the cuticle;
k, blind end of ovary;
l, location of the vulva;
m, nucleus of egg;
n, anus;
o, one of the three caudal glands;
p, spinneret.

the worms are hairy thruout. The mouth cavity is very small, prismoid and unarmed. Three obscure lips occur. Neither the Jamaican species, *T. major*, nor the Larat species, *T. similis*, appear to possess the cephalic alae observed in *T. cincta*. Otherwise the head on all three species has practically the same form, namely, approximately that of a quadrangular, blunt, truncated pyramid, with two edges of the pyramid ventrally submedian and the other two dorsally submedian. The four corners of the base of the pyramid project slightly and to them are attached the four cephalic setae. No labial papillae have been seen. There is some uncertainty about the function of the two pigmented submedian bodies behind the base of the neck. Their form, number and position somewhat favor the supposition that they are eye-spots, but if so they are farther back than in any species of nematode known to me. No lateral organs have been seen. There occurs uniformly in three specimens of *T. similis* an organ of considerable size in the body cavity on the ventral side just behind the oesophagus. It seems probable that this is the ventral gland and that it has a smaller companion cell in its rear, after the manner of the ventral gland in *Spilophora*, *Chromadora* and related genera.

In this species the ventral excretory pore appears to be in the seventh annule. The caudal glands are confined to the tail and empty thru the relatively massive, nipple-shaped spinneret. The female sexual organs are double, symmetrical and outstretched. The eggs appear to be deposited before segmentation begins. The male possesses a single outstretched testicle. The spicula are two in number and equal, and are accompanied by a well developed accessory piece.

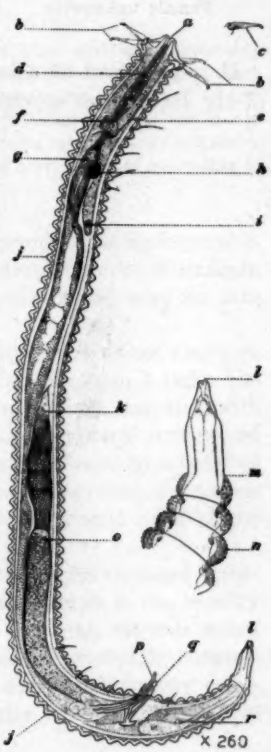

Fig. 2. Male of *Tricoma similis*, n. sp.

a, mouth and pharynx;
b, reconstructed cephalic setae;
c, drawing of single seta of another specimen;
d, esophagus;
e, excretory pore;
f, nerve ring;
g, intestine;
h, eye-spot (?);
i, ventral gland (?);
j, annule of the cuticle;
k, blind end of testicle;
l, apex of the spinneret;
m, base of the spinneret;
n, tuberculate surface of annule;
o, uterus;
p, one of the 2 spicula;
q, accessory piece;
r, one of the 3 caudal glands.

The following are the known species of *Tricoma:*

1. *T. cincta*, Cobb. Marine sand, Bay of Naples.

Dimensions unknown.

2. *T. similis*, n. sp. Larat, East Indies. Eye-spots at the twelfth annule. Male tail of eleven annules.

$$\frac{2\cdot\ 8\cdot\ 13\cdot\ 38\ 57-\ 90\cdot}{5\cdot\ 7\cdot\ 7\cdot\ 8\cdot\ 5\cdot}\ 0{\cdot}6\text{ mm.}\qquad \frac{0{\cdot}7\ 11\cdot\ 15\cdot\ 40\ -M\ 83\cdot}{2{\cdot}1\ 5{\cdot}7\ 5{\cdot}8\ 6{\cdot}5\ 6{\cdot}3}\ 0{\cdot}5\text{ mm.}$$

3. *T. major*, n. sp. Jamaica, West Indies. Eye-spots at the ninth annule. Male tail of seven annules.

				40		
Female unknown.	1·3	5·9	9·5	–M	92·	0·9 mm.
	3·4	4·5	5·4	5·6	4·2	

It is proposed at a later date to publish detailed descriptions of the latter two species.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

GEOGRAPHY.—*Kostarika: Beitraege zur Orographie und Hydrographie.* H. PITTIER in Dr. A. Petermann's Geographische Mitteilungen, Ergaenzungsheft no. 175, July 20, 1912; with a map and six profiles.

This paper gives a part of the scientific results of the author's surveys in Costa Rica, from 1887 to 1903. For the introduction, a short historical sketch of the cartography of the country is given, together with a description of the methods followed in the topographical survey and the subsequent construction of the map. This is followed by a detailed study of the mountain and river systems, with frequent discussions of the geological factors which have affected the general relief of the country.

The memoir contains also a list of nearly 500 altitudes arranged alphabetically. From this it is seen that the highest summit in the country is 3832 m., or about 12,572 feet, above sea level, an altitude much higher than has been admitted heretofore. For a concluding chapter, the author expresses his views on the much disputed boundary question between Costa Rica and Panama, and tries to show the injustice of the Loubet award.

The map is on the scale of 1: 500,000 and measures 83 x 71.5 cm. It gives in distinct colors the altitudinal zones and is executed with the usual care of all the publications of the justly celebrated German firm of Justus Perthes. The profiles are reproductions of the tours d'horizon used in connection with the astronomical triangulation of the country. H. P.

METEOROLOGY.—*Daily changes in temperature up to 4000 meters.* ALFRED J. HENRY. Bulletin Mount Weather Observatory **5**: 1–18. 1912.

This paper is a discussion of the 24-hour accidental changes in temperature of the free air from the ground to 4000 meters above sea level as determined by means of kite flights made at Mount Weather, Va. Inasmuch as only flights made on consecutive days and to approximately the same altitude could be used the total number of flights available was less than 100 and for that reason the results reached are perhaps a trifle uncertain.

The accidental changes in temperature in the free air to warmer and colder, respectively, is a subject about which comparatively little is known. On the earth's surface, however, it is known that in a general way changes to lower temperature are greater in magnitude and occur with greater frequency than those of an opposite character. In a measure this is also true of the free air up to the altitude mentioned. There appears to be a point in the free air above Mount Weather where the accidental changes are at a maximum value. In rising temperature in winter the accidental changes are greatest between the 1 and 1½ kilometer levels above sea where they are several degrees greater than at the ground on the mountain top. This is also true of falling temperature, the greatest change, however, extends thru a deeper stratum, viz., from the first to the second kilometer above sea or from 1553 to 4833 feet above the mountain top. This characteristic is much less pronounced in summer than in winter.

A comparison between the temperature of the free air in the ascent and the descent of the kites, respectively, shows that the temperature of the air is changing by small amounts practically all the time. Naturally the greatest changes are recorded under the influence of a nearby storm-center, as when a warm southerly wind is replaced by a cold northerly one. A typical case was investigated; it showed an hourly fall of 0.9°C. which if continued for 24 hours would amount to 21.6°C. or 39.6° F. This amount is believed to closely approximate the true daily fall under extreme weather conditions.

It was found that changes in the free air temperatures above Mount Weather in the layers below 4000 meters occurred under very definite pressure distribution, that is to say, changes to higher temperatures almost invariably occur when the region to the east and northeast is occupied by an area of high pressure and the Mississippi valley or the upper Lake region is occupied by low pressure. Mount Weather is

then in the transition region between a high which is retreating to the eastward and a low which is advancing from the west. In cases of falling temperature in the free air the pressure distribution just described is reversed.

The pressure distribution in the two cases above mentioned are practically those which control accidental temperature changes in the air which rests upon the earth's surface whence it appears that the entire mass of the lower air up to at least 4000 meters, 2.5 miles is similarly conditioned with respect to accidental temperature changes. That accidental temperature changes such as those discussed in this paper do not cease at the 4000 meter level is evidenced by the sounding balloon ascensions made under the direction of the Mount Weather Observatory.

A J. H.

PHYSICS.—*Instruments and methods used in radiometry. II.* W. W. COBLENTZ. Bulletin Bureau of Standards **9**: 7–63. 1912.

In this paper is given an account (see Bulletin, Bur. of Stds., Reprint No. 85) of the recent development and improvement of spectral radiation instruments. This includes air- and vacuum bolometers, thermopiles, and radiomicrometers: new combinations of instruments; linear and surface thermopiles of bismuth-silver of high sensitivity; and (Note I) the Callendar radio-balance.

The aim of the research was the production of instruments of precision rather than the attainment of high sensitivity. The vacuum bolometer was found to excel all the other types of radiometers in accuracy, in speed, and in range of sensitivity. The instrument is difficult to handle and for most work the bismuth-silver thermopile is recommended. The latter is as sensitive as a bolometer. The novelty of this type of thermopile is the solid surface which is exposed to radiation, thus utilizing all the energy from a spectral line, which is not possible with the type of iron-constantan thermopile in present use. The various modifications of these thermopiles are applicable to radiation pyrometers, sunshine recorders, and thermogalvanometers for measuring weak alternating currents.

W. W. C.

CHEMISTRY.—*On a modified form of stability test for smokeless powder and similar materials.* H. C. P. WEBER, Bureau of Standards. Bulletin Bureau of Standards **9**: 119–129. 1912.

The stability test is a form of the so-called explosion test. In the German test the sample is heated to 135°C. and the length of time is

noted until the sample explodes. In the other form of high temperature test the temperature of the sample is gradually raised until a point is reached at which the sample explodes or at least decomposes with explosive violence.

The decomposition of products of this class is exothermic and autocatalytic and the temperature of the decomposing material may be few or many degrees removed from the temperature of the heating bath. The amount of this difference will depend on a number of variables, such as the mass of the material, its heat conductivity and the heat conductivity of the systems used for test. These factors enter into the German 135° test as well as into the ordinary high temperature explosion test. In the former, the time will vary with the heat insulation, in the latter the explosion temperature will vary with the rate of heating.

The proposed test consists in the determination of a time temperature explosion curve. The samples are chosen small enough to practically eliminate the factor of heat conductivity of the sample. The apparatus consists of a heating bath which may be kept at various constant temperatures. For this work the temperatures chosen were 200°C.; 180°C.; 170°C.; 160°C. The length of time necessary for a sample to explode is determined with the aid of a stop watch at one constant temperature and then at the next and so on. The results are plotted in a curve with time and temperature as ordinates and abscissae.

That the results are reproducible to within a few per cent is shown by numerous repetitions. After the curve has been plotted by means of three or four points, determinations made at intermediate temperatures fall on the curve. The curve is therefore characteristic of the sample. It represents in effect the rate of change of decomposition velocity with change of temperature and as such is an index of the stability of the powder.

Inspection of the curves show that for stable powders there is a pronounced bend, while the ratio of explosion periods at 200°C. and 160°C. is at least 2 : 9. In the unstable powders this ratio falls as low as 2 : 3 and the irregularities become greater. It also becomes evident that one explosion temperature, even if time is considered, does not give much information.

It is possible that with sufficient accumulated data the test may throw some light on the actual effect of a stabilizer on the natural decomposition velocity of powders.

A short résumé of the literature on stability tests is given.

H. C. P. W.

CHEMISTRY.—*Application of the dimethyl sulfate test for determining small amounts of petroleum or asphalt products in tars.* CHARLES S. REEVE and RICHARD H. LEWIS, Office of Public Roads. Eighth International Congress of Applied Chemistry, 1912.

This paper, after briefly reviewing the literature on the dimethyl sulfate test, notes that the best method to date fails to detect the presence of open-chain hydrocarbons in tar-asphalt mixtures when the asphalt or petroleum is 10 per cent or less of the mixture. Commercial specifications are now being drawn which require less than 10 per cent of asphalt in mixtures with tar. The authors proceed to show that as low as 3 per cent of asphalt or petroleum can be detected in these mixtures by making the dimethyl sulfate test on higher boiling fractions (315°C.–350°C. and 350°C.–370°C.). Tables of experimental data are given.

The results do not give any absolute idea of either the amount or exact nature of the material which has been fluxed with the tar. It is thought possible, however, that the improvement which has been made in the test will enable the chemist to ascertain whether his specifications are being fulfilled, by checking up the material supplied against laboratory mixtures of the same amount and grades of materials required. C. S. R.

ANALYTICAL CHEMISTRY.—*Determination of manganese as sulfate and by the sodium bismuthate method.* WILLIAM BLUM. Bulletin of the Bureau of Standards **8**: Reprint 186.

Manganous sulfate is the only compound adapted to accurate weighing of manganese, either in gravimetric analysis, or in obtaining a definite amount of manganese as a primary standard. Of the various volumetric methods considered, the bismuthate method appeared to be most nearly free from the influence of the precise conditions of operation, and therefore most suitable for use as a standard method.

This method depends upon the oxidation of manganese to permanganic acid by sodium bismuthate in nitric acid solution. After filtration thru asbestos to remove the excess of bismuthate, ferrous sulfate is added in slight excess, which is then titrated with permanganate of known manganese value and of known ratio to the ferrous sulfate. The method of standardizing the permanganate is of course fundamental, and forms the principal subject of this paper. The manganese value may be determined by two general methods: (a) titration of a known amount of manganese, e.g., as $MnSO_4$, under the conditions of opera-

tion; and (b) calculation from the oxidizing value of the permanganate, derived from some accurate oxidimetric standard, such as sodium oxalate. The former would be more satisfactory, provided a simple and accurate means of obtaining a known amount of manganese is available. Otherwise the latter is preferable, tho it involves the use of a conversion factor, which may be either theoretical or empirical. Since Brinton and others claimed that the sodium oxalate values were 1 per cent lower than those derived from manganous sulfate, the subject was studied in detail.

A study of the standardization of permanganate with sodium oxalate showed that the conditions recommended by McBride must be slightly modified for use with 0.03 N permanganate, the strength usually employed for the bismuthate method; since the relative errors caused by variation in conditions with 0.03 N permanganate may be much larger than with 0.1 N. By the use of a small volume in the titration the errors from this source are reduced to a minimum.

After it was found that heating for a considerable period at temperatures of 450–500° is necessary to obtain anhydrous normal manganous sulfate, and that the salt does not begin to decompose unless heated above 550°, solutions of known manganese content were prepared by dissolving a definite weight of manganous sulfate which had been heated to constant weight at 450°–500°.

A study of the effect of conditions upon the bismuthate oxidation, showed that for amounts of manganese up to 0.05 gram, accurate results may be obtained over a wide range of conditions, viz., at from 5° to 25° in a volume of 50 to 150 cc., containing 20 to 40 per cent nitric acid by volume, filtration after standing one-half minute or one-half hour with bismuthate; addition of ferrous sulfate immediately or after one-half hour. The results were accurate in the presence of as much as 3 grams of iron. Addition of phosphoric acid to the ferrous sulfate solution rendered the end points more distinct. The only conditions found which yielded inaccurate results were (a) deficiency of nitric acid, (b) failure to agitate after addition of bismuthate, and (c) allowing the solution to stand after addition of the excess of ferrous sulfate. For analyses of rich ores and similar high grade materials, the use of 0.1 N permanganate is recommended, permitting the use of about 0.1 gram sample.

Experiments upon seven permanganate solutions, of different strength (0.03 N and 0.1 N), prepared from different sources, showed that the values derived from sodium oxalate and manganous sulfate agreed in

every case to within 1 part in 500. The accuracy of these values was confirmed by analysis of specially purified potassium permanganate crystals and by additional experiments upon the reduction and reoxidation of permanganate solutions. Comparative analyses of the Bureau of Standards manganese ore, as well as other ores, showed that the tendency of many of the commercial methods is to yield high results for manganese.

The bismuthate method is recommended as equal or superior to any other known methods for the determination of manganese, whether present in large or small amounts. W. B.

BOTANY.—*The branching habits of Egyptian cotton.* ARGYLE MCLACHLAN. Bulletin Bureau of Plant Industry No. 249. 1912.

The relationships of the two kinds of branches of Egyptian cotton are discussed. Vegetative branches are borne either in or outside the leaf axils at the lowest ten nodes or so of the main axis and are frequently nearly as large as the axis in actual length and in number of nodes. They do not bear flower buds, but, like the main axis, bear fruiting branches.

Fruiting branches are borne outside the axil at each node of the main axis, beginning at about node 12 from the base; they are shorter than vegetative branches, being only 6 to 8 nodes long; bear a flower bud at each node opposite a leaf, and are further distinguishable by the long basal internode. Fruiting branches borne by vegetative branches are termed secondary fruiting branches. Seemingly axillary fruiting branches occur on the main axis and on fruiting branches. It has been suggested that the first mentioned are secondary fruiting branches of axillary vegetative branches themselves suppressed.

A large vegetative branch and a fruiting branch never occur together at a node in Egyptian cotton. The further facts, that a vegetative branch sometimes replaces a fruiting branch; that branches of intermediate form with long basal internode, robust growth and no flower buds occur infrequently in the places of fruiting branches; and that cases of fruiting branches as low as node 5 or 6 of the main axis have been observed indicate that homology may exist between large basal vegetative branches and fruiting branches, rather than between the large basal vegetative branches and axillary vegetative branches of smaller size which sometimes occur with fruiting branches. A few nodes on the main axis above the basal vegetative branches but below the fruiting branches usually bear no branches, but sometimes produce abortive branches or branches of an intermediate nature.

Some fluctuation in number and size of vegetative branches and in location of the earliest fruiting branch is observed in different locations, on different soils, and under various modes of culture, the habits of branching of Egyptian cotton being governable to large extent thru cultural means. A. M.

BOTANY.—*On the identity of Cyathea multiflora, type of the genus Hemitelia R. Br.* WILLIAM R. MAXON. Bulletin Torrey Club **38**: 545–550. Pl. 35. 1911 (published January 6, 1912).

In the original description of *Cyathea multiflora* the source of the specimen was given as Jamaica. It is here shown, after examination of a photograph and fragments of the type that it agrees with none of the many elements commonly included in *Hemitelia multiflora* but represents, instead, a rather common species of Central America usually known as *Hemitelia nigricans* Presl. Further data at hand indicate that the citation of Jamaica as the original locality is erroneous. The paper is illustrated by a photograph of the type in the Banksian Herbarium.

P. C. STANDLEY.

BOTANY.—*Studies of tropical American ferns. No. 3.* WILLIAM R. MAXON. Contr. U. S. National Herbarium **16**: 25–62. Pls. 18–34. 1912.

The paper consists of seven parts, the first being a revision of the North American species of Hemitelia, subgenus Cnemidaria. Twenty-one species are recognized in this group, 8 of which are new, while one new combination is formed. A key is given for the determination of the species and most of them are fully described. In Further Notes on the West Indian Species of Polystichum, a new species is described from Jamaica, one new combination is formed, and brief notes are given upon other members of the genus. In the third part of the paper the name Pteropsis is adopted in place of Drymoglossum, and a key is given to the three North American species, one of which, from Costa Rica, is described as new. Under the heading of Two Unusual Forms of Dicranopteris mention is made of two aberrant specimens which seem to represent a reversion to some generalized ancestral type of the genus. In the fifth article, The American Species of Cibotium, four species are recognized, all from Mexico and Central America. The sixth, Two New Species of Notholaena, consists of descriptions of *Notholaena leonina* and *N. rosei*, both from Mexico. The concluding article, Miscellaneous Notes and Changes of Name, contains brief notes on miscellaneous species of various genera. P. C. STANDLEY.

BOTANY.—*A remarkable new fern from Panama.* WILLIAM R. MAXON. Smithsonian Miscellaneous Collection **56**: no. 24. Pp. 1–5, with 3 plates. November 22, 1911.

A description of *Polypodium podocarpum*, a new species from the Cordillera of Chiriqui. This plant is unusual for the genus in having fronds of indeterminate growth and the sori borne at the apices of lobes of the pinnae. Its morphology is otherwise peculiar.

P. C. STANDLEY.

BOTANY.—*Maturation artificielle lente de la datte Deglet-nour.* WALTER T. SWINGLE. Comptes Rendus **155**: 549–552, no. 12. September 16, 1912.

Deglet Noor date palms from Algeria, introduced into Arizona and California in 1900, have never properly ripened their fruit on the tree although the total heat in some parts of these states exceeded that necessary for the ripening of this date in the Algerian Sahara.

A satisfactory method of artificial ripening is therefore necessary. Slow artificial ripening at a low temperature gives much better results than any chemical means hitherto employed, and is perhaps still more important than the incubation system used by Prof. George F. Freeman of the University of Arizona.

Attention was first called to this new method by the transformation of unripe, yellowish, bitter fruits into delicious, amber-colored, translucent dates within ten days. These dates were in a valise and remained at a temperature of 20° to 30° C. in hotels or sleeping cars during a trip from Mecca, California, to Washington, D. C.

As it seemed probable that the slow ripening which had taken place in the valise is similar to that which takes place in the boxes of dates shipped from the Algerian or Tunisian Sahara to Biskra and Marseilles for packing and exportation, opportunity to investigate this question was taken on a trip to Africa in December, 1911. As a matter of fact, most of the dates in the boxes shipped from the Sahara are ripened by this slow process to which, however, no attention has ever been given.

Date ripening is composed of two distinct phases—the botanical ripening in which the fruit attains its size and has a ripe seed, and the true ripening during which the cane sugar becomes inverted sugar and the diffused tannin is deposited in insoluble form in the giant cells.

While the important factor in botanical ripening is heat, humidity is essential for true ripening. The air surrounding the fruit must be saturated by the moisture given off by the dates as they dry and become

wrinkled. This is the case in the boxes used for shipping the dates from the Sahara to Marseilles.

The Deglet Noor may ripen on the tree in many of the Saharan cases but this cannot take place in the southwestern United States because of the extreme dryness in the deserts.

A good system of slow artificial ripening for Deglet Noor dates may become important in Algerian and Tunisian commerce. Further experiments are necessary, however, for securing conditions of humidity and temperature best suited to this method.

MAUDE KELLERMAN.

BACTERIOLOGY.—*The virulence of Bacillus pestis of ground-squirrel origin.* GEORGE W. MCCOY and CHARLES W. CHAPIN. Public Health Bulletin No. 53, U. S. Public Health Service, 1912.

At the Federal Laboratory at San Francisco, there have been isolated during a period of three years, a large number of cultures of the plague bacillus from naturally infected ground-squirrel (*Citellus beecheyi*, Richardson). The virulence of 68 cultures was tested, wild rats being used as the test animals. One of the cultures indistinguishable from any of the others was found to be avirulent. The others were fatal to the test animals. The avirulent culture immunized against a virulent culture of the plague bacillus. G. W. M.

BACTERIOLOGY.—*A note on the susceptibility of ground-squirrels (Citellus beecheyi, Richardson) to tuberculosis.* GEORGE W. MCCOY and CHARLES W. CHAPIN. Public Health Bulletin No. 53, U. S. Public Health Service, 1912.

This paper supplements a previous one in which the presence in nature of tuberculosis among ground-squirrels was reported. The organism was shown to agree with the bovine type of *B. tuberculosis*.

The present paper reports the results of artificial infection of ground-squirrels. The results indicate that they are uniformly susceptible to the disease, death occurring in from 46 to 98 days. G. W. M.

BACTERIOLOGY.—*Immunity of wild rats (Mus norvegicus) to plague infection.* GEORGE W. MCCOY and CHARLES W. CHAPIN. Public Health Bulletin No. 53, U. S. Public Health Service, 1912.

Observations made in San Francisco three years prior to the present experiments showed that there was a considerable degree of immunity to plague infection among the wild rats. Another series of experiments

was carried out to determine the extent of immunity three years after the subsidence of the epizootic in the city. An attempt was also made to determine the relative susceptibility of rats of different sizes, and the susceptibility to varying doses of culture. It was found that three years after the epizootic many of the rats found in San Francisco were immune to plague. The size of the rats was found to be of comparatively little importance in determining the success of the inoculation but the dose of the culture had a very marked influence. G. W. M.

BACTERIOLOGY.—*Susceptibility of a ground squirrel (Ammospermophilus leucurus, Merriam) to plague.* GEORGE W. MCCOY and CHARLES W. CHAPIN. Public Health Bulletin No. 53 U. S. Public Health Service, 1912.

Ammospermophilus leucurus is a small ground-squirrel found in California. Nine of the rodents were used for the purpose of determining their susceptibility to plague. The experiments proved fatal in every case and in the majority a high degree of plague septicaemia developed.

G. W. M.

TECHNOLOGY.—*Physical testing of mechanical rubber goods.* Circular No. 38, Bureau of Standards. 1912.

This circular outlines the methods used at the Bureau of Standards for determining the physical properties of rubber and gives a brief description of the processes of manufacture, beginning with the collection of crude rubber, and including processes for reclaiming rubber. The tension test is the most widely applicable, being used to determine the more important physical properties such as elasticity, strength, and ultimate elongation. Machines and apparatus for conducting these tests have been designed and constructed at the Bureau of Standards.

In preparing samples for test a die is used which insures uniformity of size. Gage marks are placed on the test piece from which the permanent set and ultimate elongation are measured. Results of tests are shown graphically, illustrating the characteristics of various rubber compounds. The effect of continued heat at 160°F. on different rubbers is shown and these tests are being extended with a view to establishing an accelerated aging test. An analysis of the distribution of stress in a ring test piece is given showing that as a result of the uneven distribution of stress the ring method does not develop the full tensile strength of rubber. This result has been verified by tests.

P. L. WORMELEY.

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PROGRAMS AND ANNOUNCEMENTS

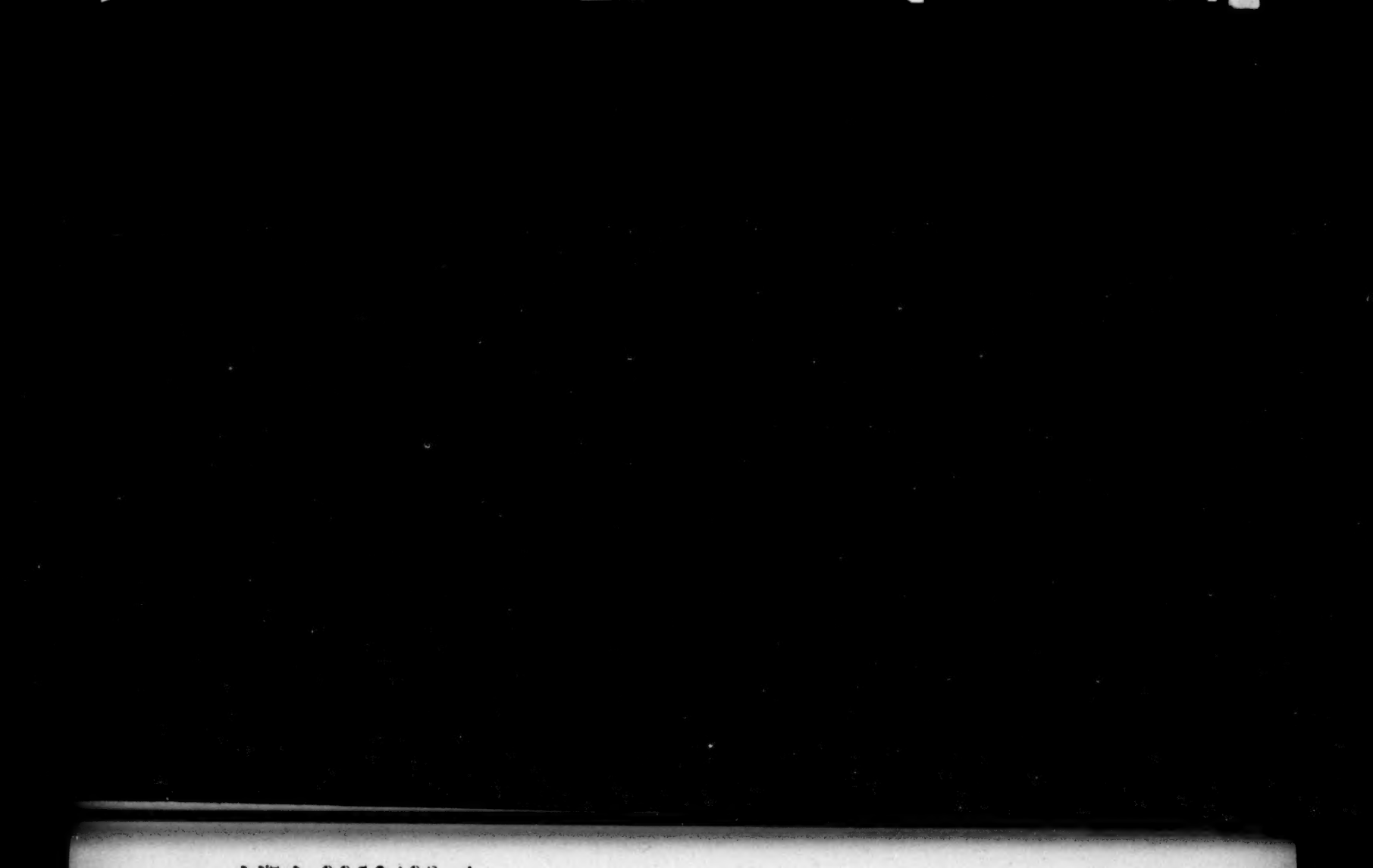
THE XIX INTERNATIONAL CONGRESS OF AMERICANISTS, 1914

In the fall of 1911 a number of delegates to the past Congresses of the Americanists met in Washington, under the auspices of the Smithsonian Institution and the Anthropological Society of Washington, for the purpose of taking preliminary steps toward extending an invitation to the Congress at its London meeting, to hold its nineteenth session, in 1914, at Washington. A temporary organizing committee was selected, consisting of Prof. W. H. Holmes, chairman; Mr. F. W. Hodge, and Dr. A. Hrdlička, secretary. This committee entered into communication with the principal local institutions and organizations which are interested in the work of the Americanists, and by May 1, 1912, a formal invitation to the Congress was agreed upon by the Smithsonian Institution, the Anthropological Society of Washington, the George Washington, Georgetown, and Catholic universities, and the Washington Society of the Archeological Institute of America. A list of names of persons to form the permanent organizing committee was agreed upon and Dr. Hrdlička was instructed to present the joint invitation with the list just mentioned to the council of the London meeting of the Americanists, which was done, and both were accepted without objection. In addition an official invitation from the Bolivian government was accepted for a second session, to be held at La Paz following that in Washington.

On October 11, 1912, the permanent committee for the Washington session met in the U. S. National Museum for organization. Its membership is as follows: Messrs. Franklin Adams, Frank Baker, Chas. H. Butler, Mitchell Carroll, Charles W. Currier, A. J. Donlon, J. Walter Fewkes, Alice C. Fletcher, Gilbert H. Grosvenor, F. W. Hodge, H. L. Hodgkins, William H. Holmes, Walter Hough, Aleš Hrdlička, Gillard Hunt, J. F. Jameson, George M. Kober, D. S. Lamb, Chas. H. McCarthy, James Mooney, J. Dudley Morgan, Clarence F. Norment, Thomas J. Shahan, H. J. Shandelle, George R. Stetson, Chas. H. Stockton, J. R. Swanton, Harry Van Dyke, Charles D. Walcott, and M. I. Weller.

The elections of officers resulted, in the main, as follows: *Patron of the Congress*, The President of the United States; *President of Organizing Committee*, Mr. W. H. Holmes, Head Curator, Department of Anthropology, U. S. National Museum; *Secretary*, Dr. A. Hrdlička, Curator, Division Physical Anthropology, U. S. National Museum; *Auxiliary Secretaries*, Dr. Chas. W. Currier and Mr. F. Neumann; *Treasurer*, Mr. C. F. Norment; *Head of General (honorary) Committee*, Dr. Charles D.

Walcott, Secretary of the Smithsonian Institution; *Committee on Finance*, Dr. George M. Kober; *Committee on Arrangements and Entertainment*, Prof. Mitchell Carroll, General Secretary Archeological Institute of America; and *Committee on Printing and Publication*, Mr. F. W. Hodge, Ethnologist in Charge of the Bureau of American Ethnology.

The sessions of the Congress will be held, thru the courtesy of the authorities of the Smithsonian Institution in the new building of the National Museum. The exact date for the meeting will be decided upon later, in accordance with the wishes of the majority of the delegates to the Congress, but the month will, in all probability, be September. Active preparations for the session, which promises to be one of the most important ever held by the Americanists, will be begun without delay.

A. HRDLIČKA,
Secretary of the Committee on Organization.